the efficiency and safety of surface operations, but that further gains may be realized by incorporating revolutionary changes to surface operations such as the use of data link and airborne taxi clearances.

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Hybrid Systems

George Meyer

It is the central tenet of the Free Flight concept that the proper distribution of real-time decision-making between users and air traffic service providers will improve system safety and efficiency. Consequently, it is important to thoroughly understand the trade-off between centralized and decentralized information flow and control for such large systems. Technically such systems are difficult to analyze because they are composed of many objects that interact in a complex and hybrid environment. At present there are no effective analytical tools for use in the design and analysis of such systems. The objective of the present task is to contribute, through university research grants and internal research, to the development of such tools, and to then apply them to the specific case of air traffic management. The participating universities are the University of California at Berkeley, University of Utah, University of Illinois at Chicago, Wayne State University, Case Western Reserve University, and State University of New York at Stony Brook.

One approach that is followed is to try to understand in detail simpler problems and to then generalize the results to the real problem. An example is shown in the figure. The system evolves on a rectangular grid, and only two-dimensional motion along the grid is permitted. There are sources injecting objects representing individual flights into the grid and sinks absorbing the objects. Sources and sinks may represent departure and arrival airports or entry and exit cells at a given flight level. In the figure, the cell at (1,1) is both a sink for gray objects and a source of black objects. Conversely, the cell at (12,14) absorbs black and injected gray objects, respectively. In the example there are only two colors; in the general case there may be many more. Each object attempts to minimize the total number of steps that it takes to move from source to sink. There are many solutions for each object. Safety dictates that occupation of the same cell or the interchange of cells is forbidden. System cost is the conflict-free total deviation from the sum of individual minima. The following questions are addressed: Does a given departure schedule have a zero-cost solution? Does a given pattern on the grid have a zero-cost solution? In either case if there is a solution, can the solution be constructed with only local information and local rules and decisions, or are global information and central control necessary? If there is no zero-cost solution, then what are the minimum-cost solutions? What is the most efficient modification of the schedule or pattern? The key objective of the research is to obtain answers to these questions analytically and only from the properties of schedules and patterns. Progress has been made in this direction, and theorems have been developed that guarantee local cost-free solutions.

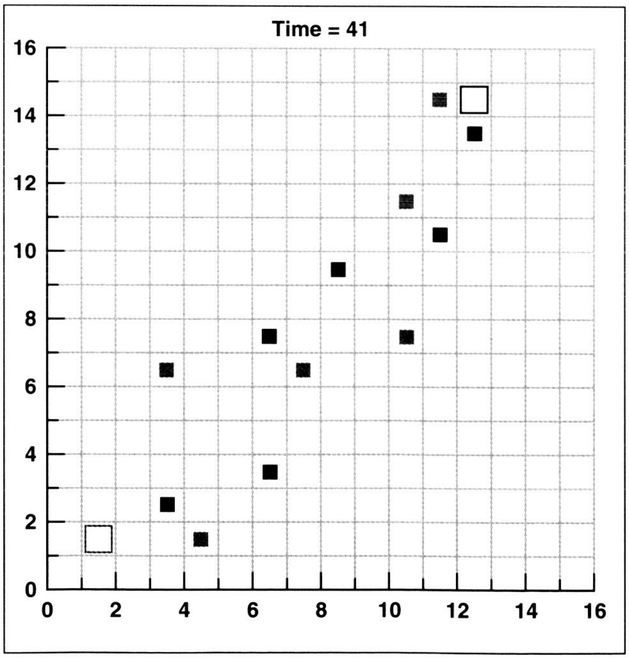

Fig. 1. An example configuration.

For example, according to one theorem, if (1) the source/sink pair is not inline, (2) the pair is separated by a distance that is a multiple of four, (3) the time of departure for one color is a multiple of four, (0, 4, 8,...), and (4) that of the other color is the same but staggered by two, (2, 6, 10,...), then all conflicts are resolvable by local one-one negotiation. Consequently, the pattern in the figure is solvable without central control. On the other hand, several resolvable configurations that require central control have also been found. The objective of the work on this cellular model of air traffic management is to complete the theory for the two-color case, and then extend the results to more colors.

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Inflight Activity Breaks Reduce Sleepiness in Pilots

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Flight operations often result in fatigue, sleep loss, and circadian disruption leading to significant decrements in alertness and performance. These problems can be difficult to detect reliably and to counteract effectively in constrained operational environments such as the flight deck. Left unaddressed, alertness and performance decrements reduce the margin of safety and increase the chances of an incident or accident. One serious challenge facing flight crews is the requirement to maintain vigilance during long, highly automated, and often-uneventful nighttime flights.

Currently there is no system in place to assist flight crews in managing their alertness. Furthermore, strategy choices are severely restricted in the flight deck environment. For example, although previous research has demonstrated the effectiveness of a 26-minute nap in significantly improving subsequent physiological alertness and performance, the FAA does not currently sanction napping on the flight deck. Current Federal Aviation Regulations also mandate that flight crews remain seated ("...each required flight crewmember on flight deck duty must remain at the assigned duty station with seat belt fastened while the aircraft is taking off or landing, and while it is enroute") with but a few exceptions.

Nevertheless, surveys of flight crews reveal that many use physical activity as a countermeasure during fatiguing flights. Despite this widespread belief by flight crews in the effectiveness of physical activity, there have been no controlled studies of its effect on vigilance, sleepiness, and performance in the aviation environment. This flight simulator study examined whether regularly spaced brief bouts of controlled physical activity (standing up, walking, stretching) combined with social interaction could improve alertness and performance during a long, uneventful, overnight flight requiring extended wakefulness and vigilance. The data obtained from this study support NASA's Aero-Space Technology Enterprise and its objective of reducing the aircraft accident rate.

Fourteen two-man crews flew a 6-hour (2:00-8:00 a.m.) uneventful flight from Seattle to Honolulu in the Ames 747-400 flight simulator. The 14 subjects in the Treatment Group received five short (7-minute) breaks with controlled physical activity and social interaction, spaced hourly during the cruise portion of the flight. An equivalent number in the Control Group received only one 7-minute break in the middle of cruise. Measures of psychomotor vigilance performance, subjective sleepiness, continuous brain wave activity (electroencephalography; EEG), and continuous eye movement activity (electrooculography; EOG) were collected throughout the flight.

Treatment subjects receiving the hourly activity breaks reported significantly greater subjective alertness when it was measured at 5, 15, and 25 minutes post-break, with the strongest effects near the time of the daily circadian trough in alertness (~5:00-6:30 a.m.). The benefit in subjective alertness dissipated by 40 minutes post-break, and there was no evidence of objective vigilance performance improvement when it was sampled from 15 to 25 minutes post-break. There was the expected performance deterioration in both groups because of an elevated sleep drive and the circadian time of day. However, during the latter part of the night, the EEG and EOG measures for the Treatment Group revealed statistically significant post-break reductions relative to the Control Group in slow eye movements, EEG